(12) UK Patent Application (19) GB (11) 2 049 922 A

(21) Application No **8012879**
(22) Date of filing **18 Apr 1980**
(30) Priority data
(31) **3666/79**
(32) **18 Apr 1979**
(33) **Switzerland (CH)**
(43) Application published **31 Dec 1980**
(51) INT CL[3] **F24H 7/02**
(52) Domestic classification **F4U 60 70**
(56) Documents cited **None**
(58) Field of search **F4U**
(71) Applicants **Sulzer Brothers Limited, CH—8401 Winterthur, Switzerland**
(72) Inventor **Alexander Stuecheli**
(74) Agents **Kilburn & Strode**

(54) **Process for improving the heat exchange in a latent heat store, and apparatus for performing the process**

(57) In a process for achieving heat exchange in a latent heat store 10, between a heat storage medium 14 and a heat vehicle medium 37, by way of a heat transfer surface 30 separating the two media, the heat storage medium 14 (e.g. a grit) is brought into a fluidized state by a fluidizing medium e.g. a paraffin oil 16 (or air or an inert gas, Fig. 3) which is substantially immiscible with the heat storage medium. A temperature sensor 39 may control a pump 20 to regulate the degree of fluidization. The heat vehicle medium 37 may be a water-glycol mixture circulated through a solar heat collector 36 or through the evaporator of a heat pump (e.g. 56, Fig. 2). The heat store 10 may provide heat for a heating or hot water system (e.g. *via* a circuit 40, 42, 44). Supplementary heat for the heat store may be provided by an electric heater 48 or by an oil burner (e.g. 70, Fig. 2) in the circuit 40, 42, 44.

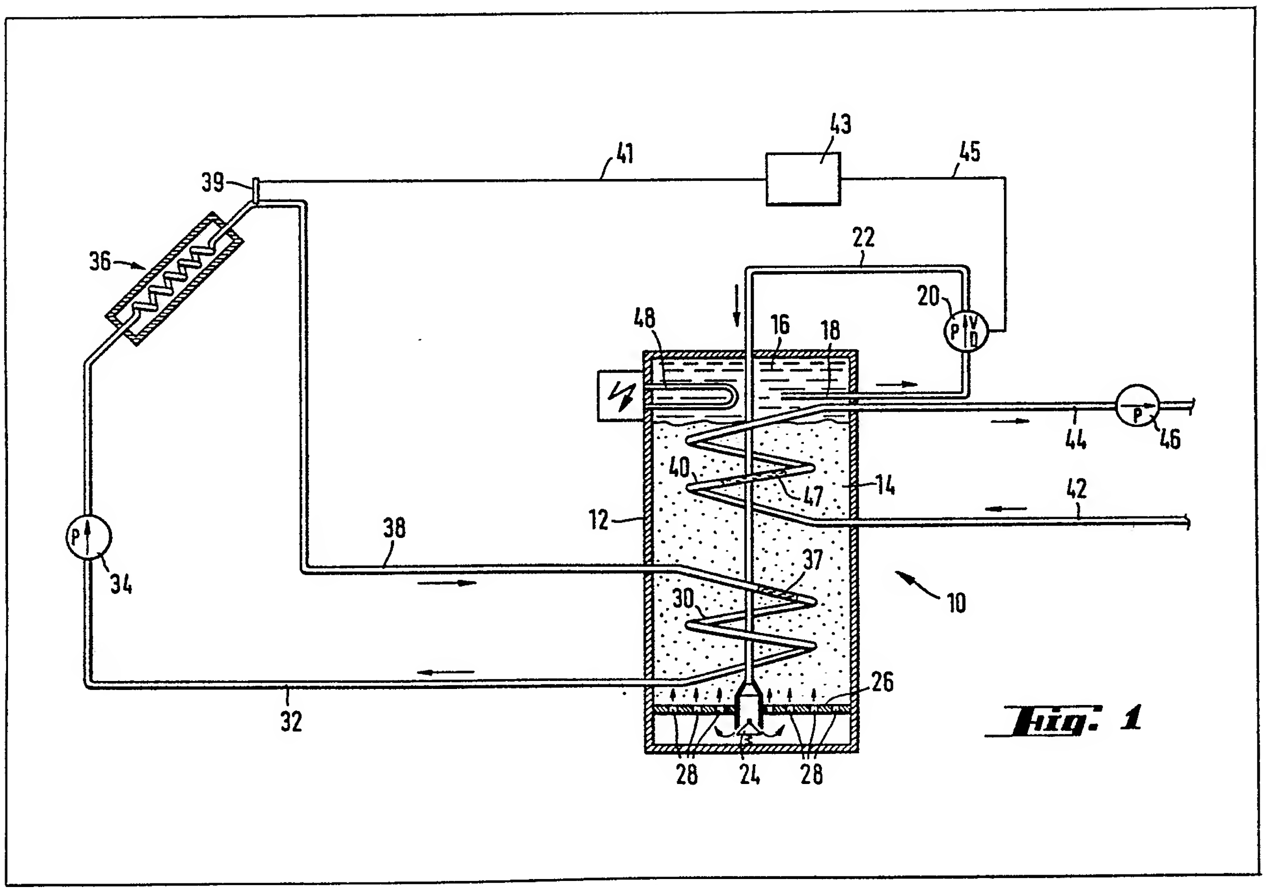

Fig. 1

GB 2 049 922 A

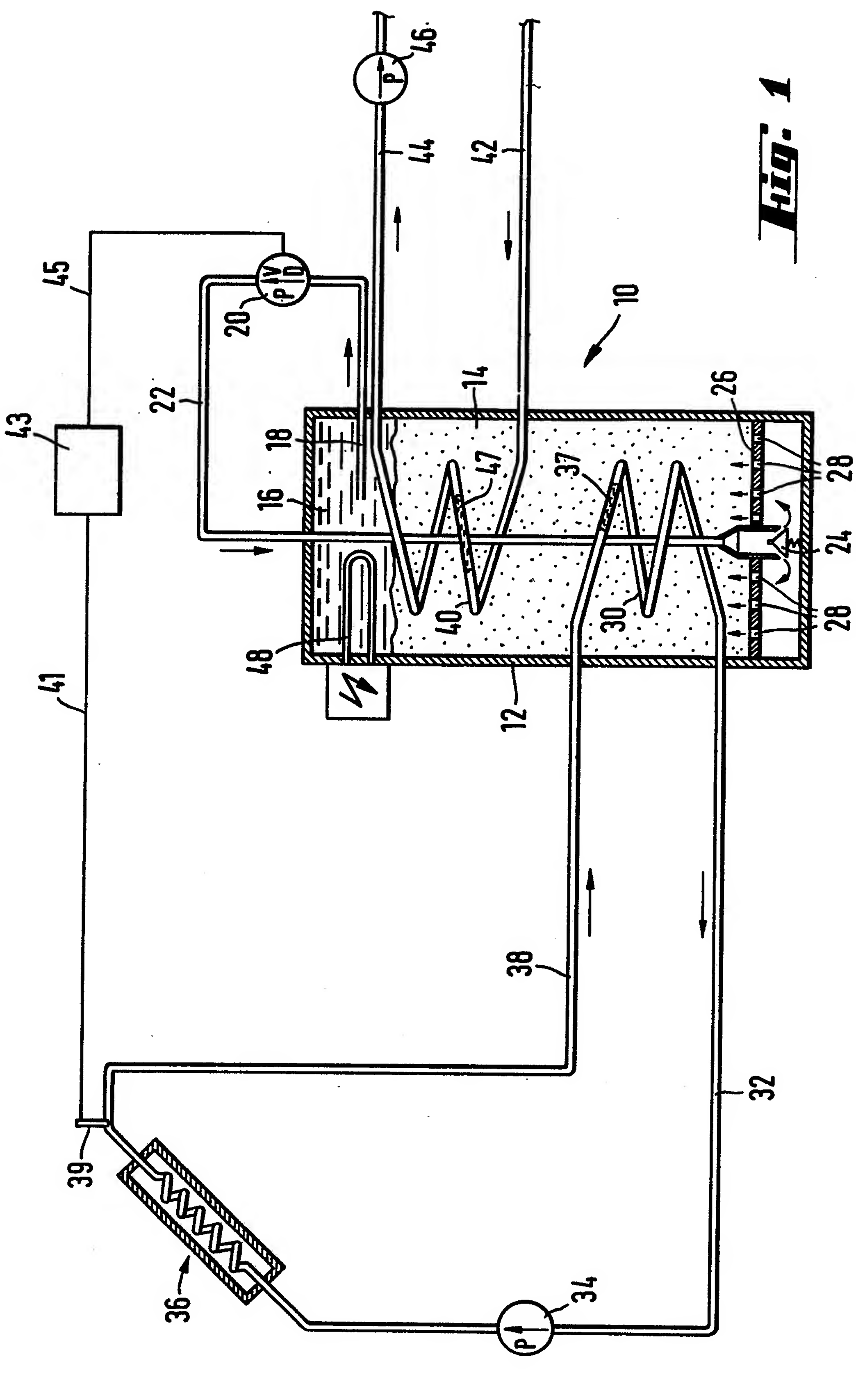
46
P
44
42
45
20
P
V
D
10
22
43
18
14
47
37
26
28
16
24
48
40
30
28
41
12
38
32
39
36
P
34

Fig. 1

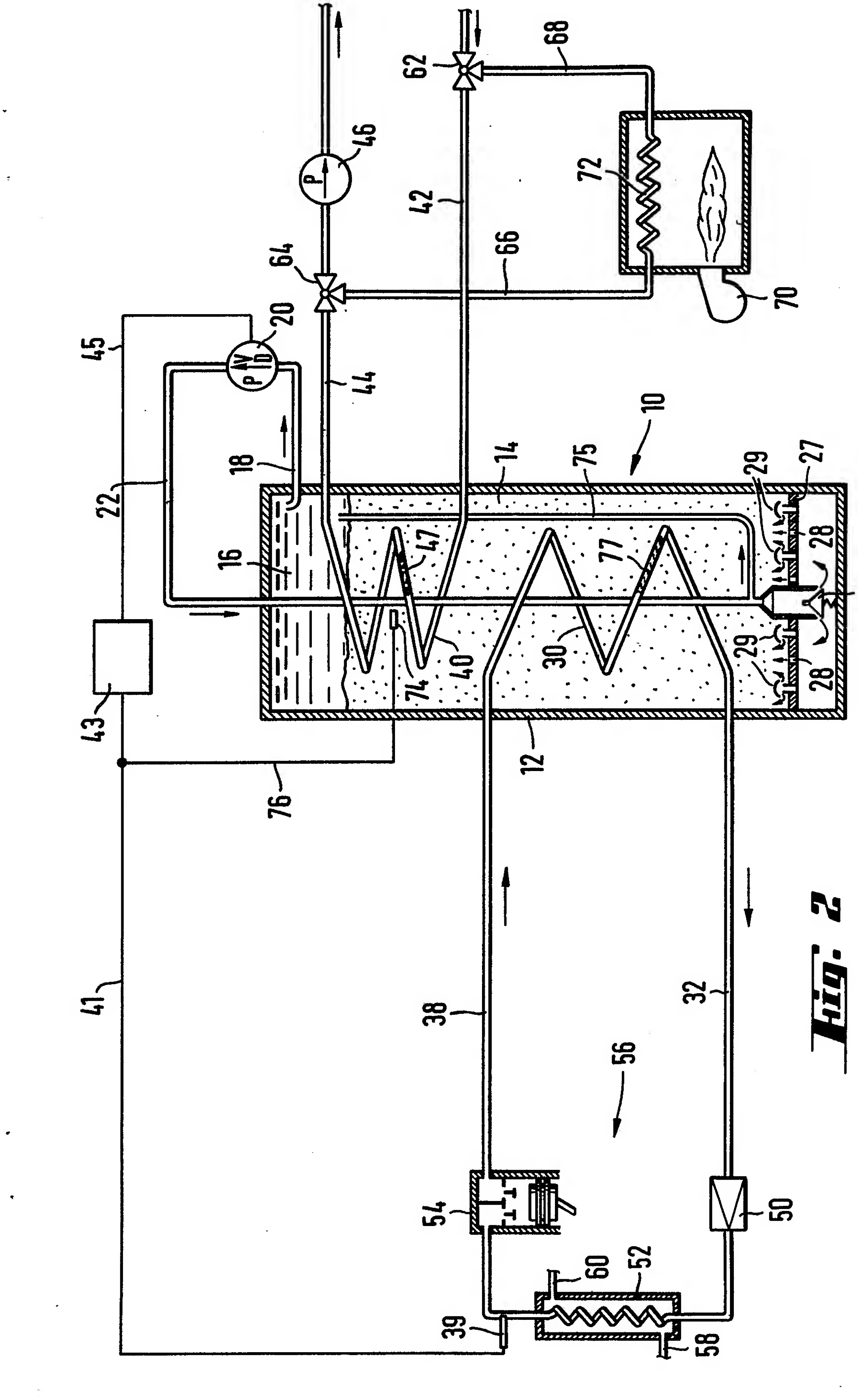
10
12
14
16
18
20
22
24
27
28
29
30
32
38
39
40
41
42
43
44
45
46
47
50
52
54
56
58
60
62
64
66
68
70
72
74
75
76
77
P
AV
ID

Fig. 2

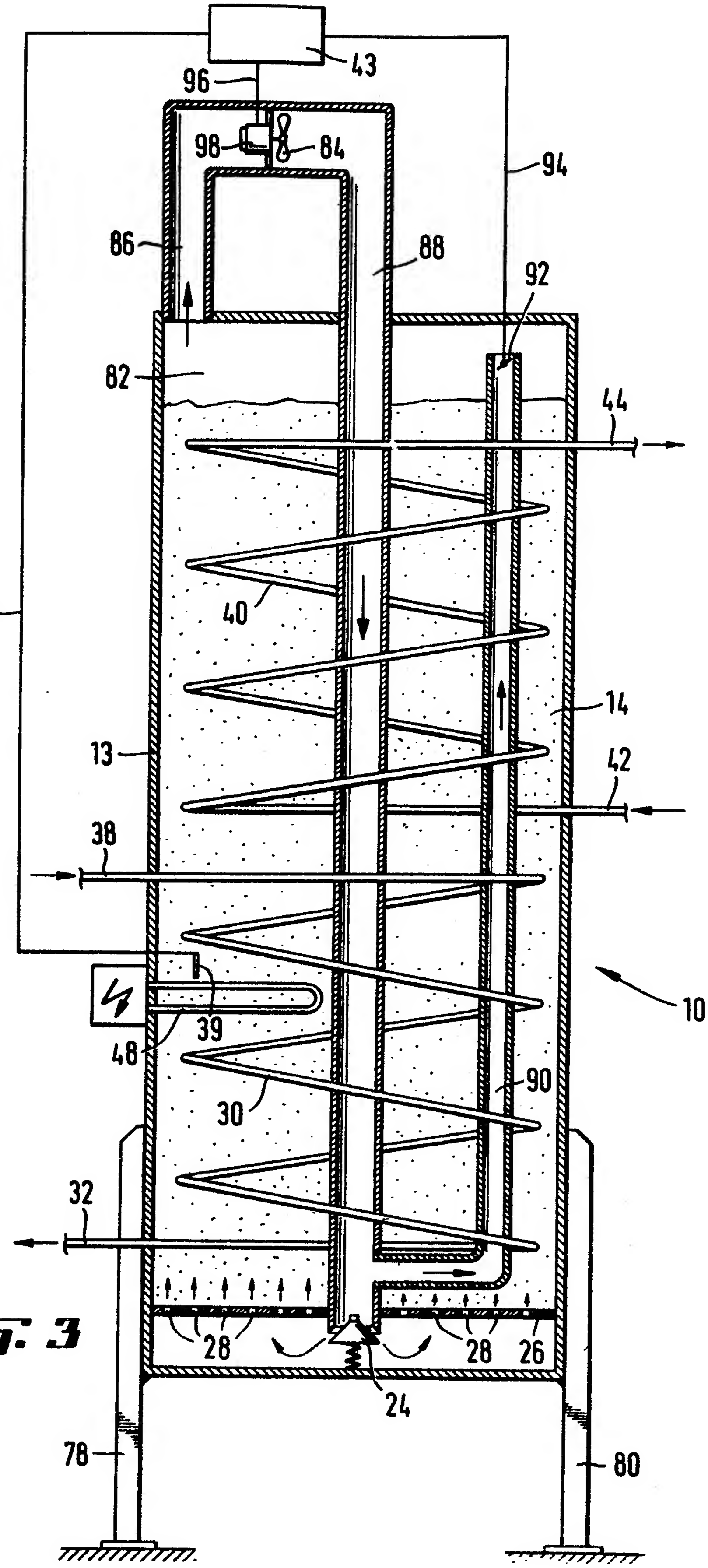
43
96
98
84
94
86
88
92
82
44
40
41
14
13
42
38
10
39
48
90
30
32
28
28
26
24
78
80

Fig. 3

SPECIFICATION

Process for improving the heat exchange in a latent heat store, and apparatus for performing the process

This invention relates to a process for improving the heat exchange in a latent heat store, the heat exchange taking place between the latent heat storage medium and a heat vehicle medium, by way of a heat transfer surface separating the two media, and to apparatus for performing the process.

Various heat storage substances having high latent heats of fusion are used in latent heat stores. These substances absorb large quantities of heat, e.g. solar heat, and melt in so doing. If their heat is subsequently withdrawn, e.g. overnight or during cloudy weather conditions, the material re-freezes and in so doing yields up the stored heat. Examples of latent heat storage media are water, paraffin wax and, in particular, sodium salts which contain water of crystallization. By way of example, the heat storage capacity of sodium sulphate containing water of crystallization is about 7 times that of the same volume of water.

The practical use of such sodium salt hydrates was hitherto accompanied by various disadvantages. For example, with latent heat stores of this kind an intrusive layer of salt forms on the heat transfer surfaces as well as the tank walls during the freezing process, so that the heat transfer is greatly impaired. With some types of salts, the freezing process is accompanied by grit or floc formation, the heat transfer again being greatly reduced. Of course the latent heat storage medium may also solidify into a substantially homogeneous block, e.g. when paraffin wax is used, and in that case re-melting by heat transfer surfaces present in the medium is very time-consuming because of the poor heat transfer. Another aggravating factor may be solid-liquid phase separation, e.g. sodium salt/water, which practically prevents congruent re-crystallization of a storage substance of this kind.

The same problems apply if just water is used as the latent storage medium instead of such sodium salt hydrates. A latent heat storage device of this kind based on ice/water is described, for example, in US Patent Specification No. 2,996,894, in which the attempt is made to avoid the problem concerning incrustation, i.e. icing in this case, on heat exchange surfaces, by dispensing with the conventional indirect heat exchange between the heat vehicle medium and the latent heat storage medium. Instead, a liquid heat vehicle medium, oil in this case, is brought directly into contact with the water storage medium, is separated from the water after the heat exchange is complete, and is pumped, for example, through a heat exchanger outside the latent heat store in order to withdraw or supply the heat.

Such use of oil for direct heat exchange with water is accompanied by various disadvantages however. For example, oil has a relatively low thermal capacity and for this reason alone is unsuitable as a heat transfer medium. Also, it is in practice very difficult to effect the required separation between oil and water after the heat exchange, since an irreversible emulsion can readily form. The greatest possible mixture of oil and water, is however, essential if the heat transfer is to be in any way satisfactory, and such a mixture promotes the formation of emulsions. If the oil is mixed with or pumped through the water at only low intensity in order to reduce the risk of an emulsion forming, the oil/water heat transfer is inadequate. A direct heat exchange of this kind is also impossible if, for example, the working medium of a heat pump is to be used as heat vehicle medium. A latent heat store of this kind is thus unsuitable for the purposes of the invention.

The object of the invention is to obviate the above disadvantages of a direct heat exchange between the latent heat storage medium and a liquid heat vehicle medium, and the disadvantages occurring in the case of indirect heat exchange between the latent heat storage medium and a heat vehicle medium by way of a heat transfer surface, and so improve the heat exchange in a latent heat store of the kind referred to hereinbefore that even if the latent heat storage medium is in grit form, for example, intensive contact between the whole of the storage material and the heat transfer surfaces is guaranteed with a high heat transfer. Also, if the latent heat storage medium is in caked or block form, the invention is to allow rapid melting or homogenization so that optimum heat exchange can take place within a short period.

Accordingly the present invention provides a process for achieving heat exchange in a latent heat store, the heat exchange taking place between the latent heat storage medium and a heat vehicle medium, by way of a heat transfer surface separating the two media, in which the latent heat storage medium is brought into the fluidized state by means of a fluidizing medium which is substantially immiscible with the heat storage medium.

According to a further aspect of the invention there is provided apparatus for performing such a method comprising a tank arranged to receive the latent heat storage medium, the tank comprising at least one heat transfer surface arranged to contain a heat vehicle medium, said surface being disposed to contact the latent heat storage medium; and a forced flow circuit for the fluidising medium passing through the tank, the circuit comprising an exit from the tank, a circulating means, a supply line extending to the tank, and a diffuser arranged to diffuse the fluidizing medium for the supply line into the storage medium.

Since the latent heat storage medium can be kept in a state similar to a fluidized bed by means of the fluidising medium, not only is intensive contact ensured between the whole of the storage material and the heat transfer surface, but in addition the latent heat storage medium is

guaranteed to be ready for operation or available at all times for heat transfer purposes. If, for example, the latent heat store is not required from time to time, e.g. owing to lack of solar radiation, then only a low degree of fluidization or flow of dispersion medium is required to prevent caking or phase separation in the latent heat storage medium or incrustation of the heat transfer surfaces. If heat is to be stored or yielded up in the store, the fluidization can be intensified as required to ensure the required heat transfer. Since the fluidizing medium does not have to perform any heat transfer function, the heat transfer is not dependent upon its thermal capacity. Another advantage is that no complicated mechanical circulating means are necessary in the store itself.

In order to promote a fuller understanding of the above and other aspects of the invention, some embodiments will now be described, by way of example only, with reference to the accompanying drawings in which:—

Figure 1 is a diagram showing the process and the apparatus using liquid fluidizing medium in conjunction with a solar collector heating system,

Figure 2 shows the process and apparatus of Figure 1 in conjunction with a heat pump and an oil-fired heating boiler, and

Figure 3 shows the process using gaseous dispersion medium in conjunction with a corresponding apparatus in vertical section.

In Figure 1 a latent heat store 10 comprises a tank 12 insulated in a manner not shown, the tank being filled partly with a latent heat storage medium 14, and partly with a liquid fluidizing medium 16, e.g. paraffin oil. The top part of the tank 12 containing the fluidizing medium 16 is connected to a fluidizing or diffuser element 26 in the form of a screen or perforate tray with apertures 28. The element 26 extends basically over the entire tank cross-section in the bottom part thereof and the connection between element 26 and the top part of the tank 12 is made via an exit line 18, a variable-delivery pump 20, and a supply line 22 which extends as far as the bottom part of the tank 12 and has a non-return valve 24 at its outlet end. A first heat transfer surface in the form of a tube coil is disposed in the tank 12, contains a heat vehicle medium 37, e.g. a mixture of water and glycol, which is circulated via line 32, circulating pump 34, solar collector 36 and line 38, and is used to heat up the latent heat storage medium 14 in the bottom part of the tank 12. A thermal sensor 39 disposed in line 38 after the solar collector senses the temperature of the medium 37 and is connected to operate the pump 20 via a signal line 41, a control unit 43 and a signal line 45. A second heat transfer surface 40 in the form of a tube coil is also disposed in the medium 14 and is connected to a load circuit, e.g. a heating or hot water system, via lines 42, 44 and a circulating pump 46. In this case, therefore, medium 47 is water. An electric heater 48 provides supplementary heating in the absence of solar energy and facilitates melting of the medium 14 in the event of the latter changing to the solid form during freezing. Since this heater is not intended for storing heat in the latent heat storage medium 14, but is only intended to facilitate the fluidization process when the store is "started up", it can be disposed in the fluidizing medium 16 as shown in Figure 1.

The apparatus described operates as follows:

By way of example it will be assumed that the solar collector 36 is out of operation, e.g. during the night. The bottom part of the store 10 then contains a pasty material which is caked to varying degrees and which consists of oil and latent heat storage medium in the form of grit. It will immediately be apparent that when the store is heated up only the solid particles immediately adjacent the heat transfer surface 30, 40 can be melted in such a mixture in the static state, and that the heat transfer is very poor. As soon as the conditions for operation of the solar collector 36 occur, the pump 20 is operated via the sensor 39 so that oil 16 is delivered at a certain speed of flow via lines 18, 22 and in the direction of the arrow to the bottom part of the tank 12 and through the non-return valve 24 and the apertures 28 of the dispersion element 26. The pasty mixture is thus fluidized, i.e. it is converted from the static state to a mobile state, in which the individual solid particles of the medium form a fluidized bed and practically the entire contents of the tank come continuously into contact with the heat transfer surfaces 30, 40. The latent heat store is thus converted to the operative state with this minimum degree of fluidization. If the sensor 39 records an increase in the radiation temperature, the delivery speed of the pump 20 is increased via the control unit 43 so that the degree of fluidization in the store is intensified accordingly. The heat transfer between the surfaces 30, 40 and the medium 14 thus increases accordingly. The radiation losses of the solar collector 36, which are substantial at higher temperatures, are thus greatly reduced. Once the store 10 has been charged up, the stored heat can be withdrawn and fed to the load circuit, by way of the heat transfer surface 40, which has the fluidized latent heat storage medium flowing around it.

In the apparatus shown in Figure 2, a heat pump 56 comprising a throttle 50, an evaporator stage 52 and a compressor stage 54, is used to heat up the latent heat storage medium 14. In this case the sensor 39 is used to sense the temperature of the heat pump working medium 77, which is heated by a medium, e.g. ground water or ambient air, which is taken through supply and discharge lines 58, 60 provided in the evaporator stage 52. A tube coil 72 adapted to be heated by an oil burner 70 can also be put into the circuit via lines 66, 68 and three-way valves 62, 64 disposed in the lines 42, 44. An additional temperature sensor 74 is connected to the control unit 43 via a signal line 76. Supply line 22 additionally comprises a bypass line 75, the flow resistance of which is higher than that of the

supply line 22. In this case, the diffuser element 27 has bubble tray apertures 29 in addition to the passage apertures 28.

The above apparatus operates as follows:

The heat pump working medium or heat vehicle medium 77, e.g. one of the conventional refrigerants, is heated up in the evaporator stage 52 by the medium supplied and discharged via lines 58 and 60 respectively, is compressed in the compressor stage 54, and then condensed in the tube coil 30, which in this case acts as a condenser, the heat liberated in these conditions being yielded to the latent heat storage medium 14. Temperature sensor 39 controls the degree of fluidization of the mdium 14 as already described with reference to the example described in connection with Figure 1. After condensation and heat transfer, the working medium 77 is expanded in the throttle 50 and passes back to the evaporator stage 52 where the process described is repeated. If the temperature conditions required for operation of the heat pump 56 do not exist, the load circuit can be additionally heated by means of the supplementary heating system 66, 72, 68, 70, which can be put into circuit via the three-way valves 62, 64. The circuit can, however, be set to heat the latent heat storage medium, e.g. in order to maintain a minimum operational readiness of the store. In that case the temperature sensor 74 is used to control the degree of fluidization of the medium in such a manner than overheating at the heat transfer surface 40 is avoided. The bypass line 75 is used to maintain the circuit of the dispersion medium 16, e.g. in the event of the bottom part of the tank 12 being filled with caked latent heat storage medium 14 and the passage apertures 28 being partially clogged. The bubble tray apertures 29 are intended for the same purpose.

In the embodiment shown in Figure 3, the tank 13 of the latent heat store 10 is supported on the ground by way of posts 78 and 80. In this case the fluidizing medium 82 is air or inert gas, e.g. nitrogen. The fluidizing medium is drawn in by an axial fan 84 through a withdrawal duct 86 disposed in the top part of the tank 13, is fed to the bottom part of the tank 13 via a feed duct 88 as in the case of the supply line 22 already described hereinbefore, and flows through the diffuser element 26, the latent heat storage medium 14 being fluidized. In this case a bypass duct 90 containing a throttle valve 92 branches off from the bottom part of the feed duct 88. The cross-section of the bypass duct 90 is somewhat smaller than the cross-section of the feed duct 88. The drive (not shown) for adjustment of the throttle valve 92 is connected to the control unit 43 via a signal line 94. Another signal line 96 connects the control unit to the drive motor 98 of the axial fan 84.

The above apparatus operates as follows:

It will be assumed, by way of example, that the medium 14 is to be heated up by the electric heater 48 until the latent heat store is ready for operation. A signal transmitted by the sensor 39 causes the control unit 43 to switch on the drive 98 for the axial fan 84 and at the same time to set the valve 92 to the open position. Some of the air can thus escape through the bypass line. The degree of fluidization in these conditions is sufficient for operational readiness of the store. If the degree of fluidization is to be intensified as the temperature rises, throttle valve 92 is gradually closed so that a maximum volume of air flows through the diffuser element 26.

Of course the gaseous fluidizing medium circuit described may also contain compressors and conventional gas storage means.

CLAIMS

1. A process for achieving heat exchange in a latent heat store, the heat exchange taking place between the latent heat storage medium and a heat vehicle medium, by way of a heat transfer surface separating the two media, in which the later heat storage medium is brought into the fluidized state by means of a fluidizing medium which is substantially immiscible with the the heat storage medium.

2. A process according to Claim 1, in which the degree of fluidization of the heat storage medium is controlled in accordance with the temperature of at least one of the media taking part in the heat exchange.

3. A process according to Claim 1 or 2, in which the fluidizing medium is liquid.

4. A process according to Claim 1, 2 or 3, in which at least part of the fluidizing medium flow is brought into direct contact with the latent heat storage medium by being passed therethrough in a forced-flow circuit.

5. Apparatus for performing the process according to Claim 1, comprising a tank arranged to receive the latent heat storage medium, the tank comprising at least one heat transfer surface arranged to contain a heat vehicle medium, said surface being disposed to contact the latent heat storage medium; and a forced-flow circuit for the fluidizing medium passing through the tank, the circuit comprising an exit from the tank, a circulating means, a supply line extending to the tank, and a diffuser arranged to diffuse the fluidizing medium for the supply line into the storage medium.

6. Apparatus according to Claim 5, in which the diffuser element is a tray which extends over substantially the entire tank cross-section and which is formed with passage apertures for the fluidizing medium.

7. Apparatus according to Claim 6, in which at least some of the passage apertures are constructed as bubble tray apertures.

8. Apparatus according to Claim 5, 6 or 7 in which a non-return valve is provided between the diffuser element and the supply line.

9. Apparatus according to Claim 5, 6, 7, or 8 in which the supply line is provided with a bypass line.

10. Apparatus according to Claim 9, in which flow resistance of the bypass line is greater than

that of the supply line.

11. Apparatus according to any one of Claims 5 to 10 including means for control of the speed of flow and/or quantity of circulated fluidizing medium in dependence upon temperature.

12. Apparatus according to Claim 11, in which the circulating means is controllable by way of a sensor which senses the temperature of the heat vehicle medium and/or of the latent heat storage medium.

13. A process for achieving heat exchange in a latent heat store substantially as herein described with reference to the accompanying drawings.

14. Apparatus for achieving heat exchange between a heat exchange vehicle medium and a latent heat storage medium substantially as herein described with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1980. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.